

Sleuth

A quasi-model-independent search strategy
for new physics

Motivation

Sleuth

Results



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Motivation

Consider some recent major discoveries in high energy physics:

- | | | |
|-----------------|----------|------|
| • W, Z bosons | CERN | 1983 |
| • top quark | Fermilab | 1995 |
| • tau neutrino | Fermilab | 2000 |
| • Higgs boson? | CERN | 2000 |

In all cases the predictions were “definite” (apart from mass)

couplings known

cross section known

final states known

you were willing to bet even odds that the particle existed

We are now in a qualitatively different situation

consider the models that appear daily on hep-ph

are you willing to bet even odds on any of them?

(If so, please see me after this talk!)

Motivation

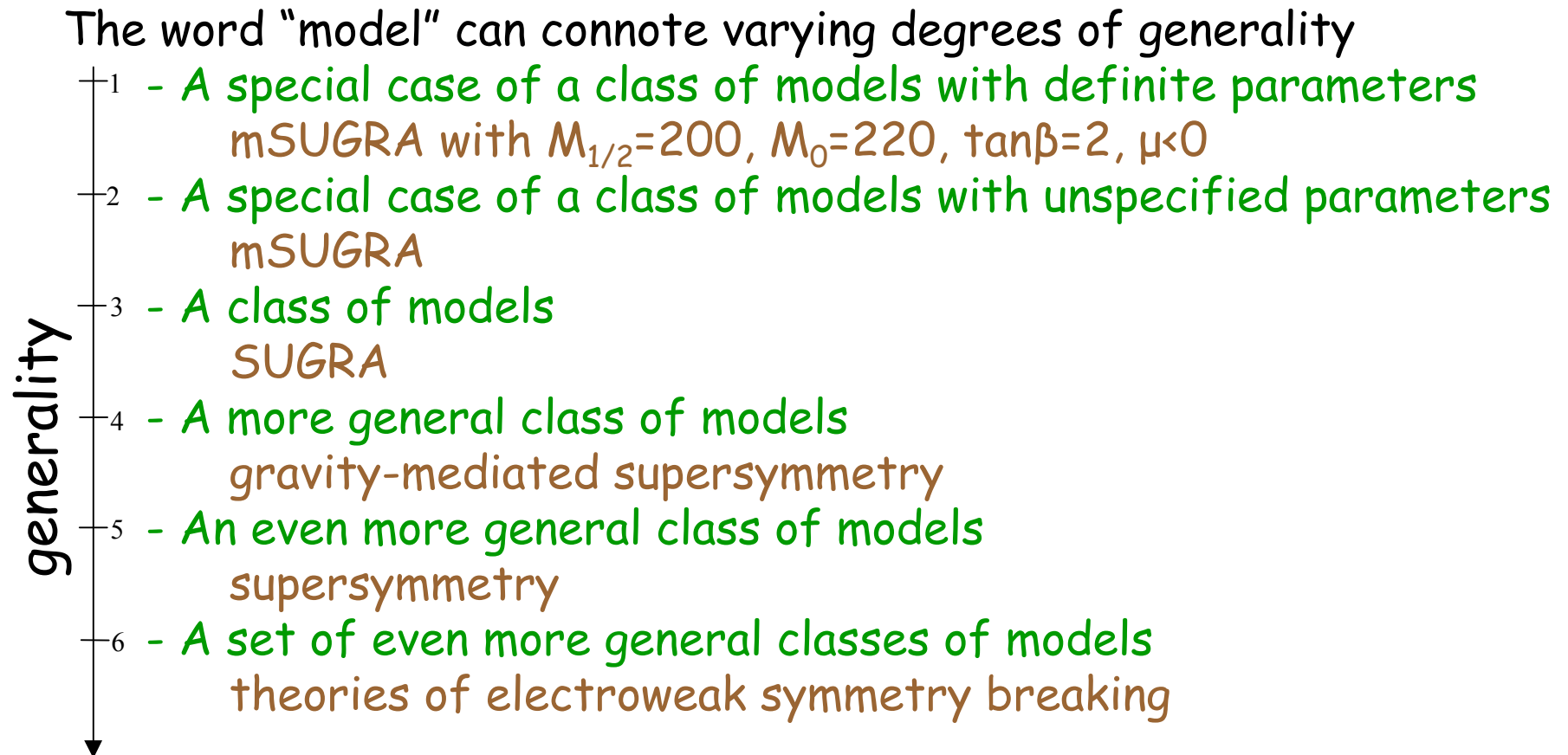
Most searches follow a well-defined set of steps:

- Select a model to be tested
- Find a measurable prediction of the model differing as much as possible from the prediction of the Standard Model
- Check those predictions against the data

This approach becomes problematic if the number of competing candidate theories is large ... and it is!

Is it possible to perform some kind of "generic" search?





Most new physics searches have generality $\approx 1\frac{1}{2}$ on this scale

We are shooting for a search strategy with a generality of ≈ 6

Motivation

a posteriori analysis?

Another related issue:

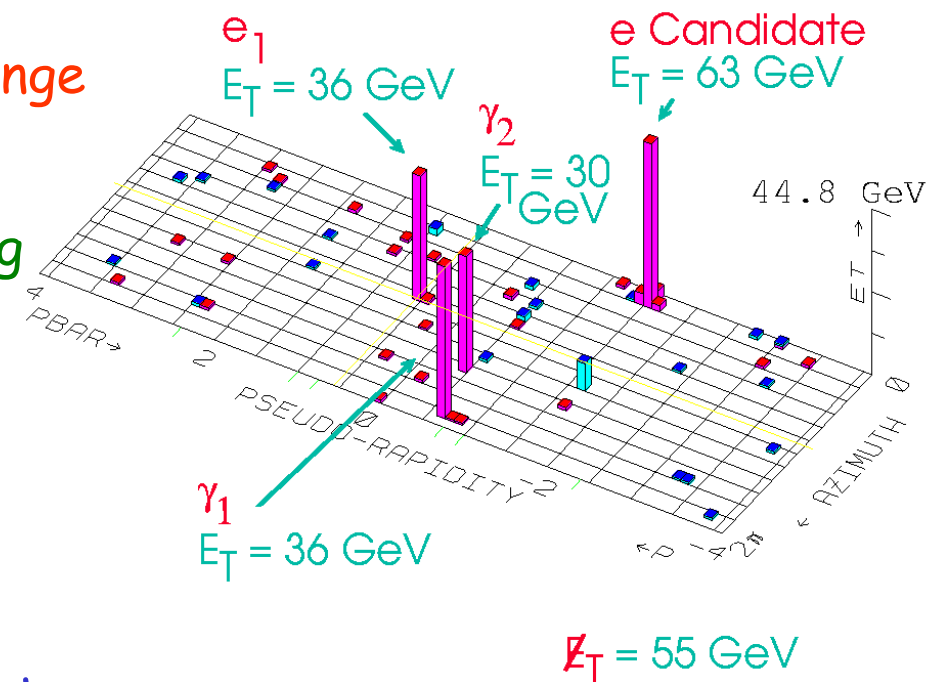
How do we quantify the
"interestingness" of a few strange
events *a posteriori*?

After all, the probability of seeing
exactly those events is zero!

How excited should we be?

How can we possibly perform an
unbiased analysis after seeing the
data?

CDF $ee\gamma\gamma Z_T$ Candidate Event



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Steps:

1) We consider exclusive final states

We assume the existence of standard object definitions

These define $e, \mu, \tau, \gamma, j, b, \cancel{E}_T, W$, and Z

All events that contain the same numbers of each of these objects belong to the same final state



2) Define variables

What is it we're looking for?

The physics responsible for EWSB

What do we know about it?

Its natural scale is a few hundred GeV

What characteristics will such events have?

Final state objects with large transverse momentum

What variables do we want to look at?

p_T 's

If the final state contains

Then consider the variable

1 or more lepton

$$\sum p_T^\ell$$

1 or more $\gamma/W/Z$

$$\sum p_T^{\gamma/W/Z}$$

1 or more jet

$$\sum p_T^j$$

missing E_T

$$\cancel{E}_T$$

(adjust slightly for idiosyncrasies of each experiment)

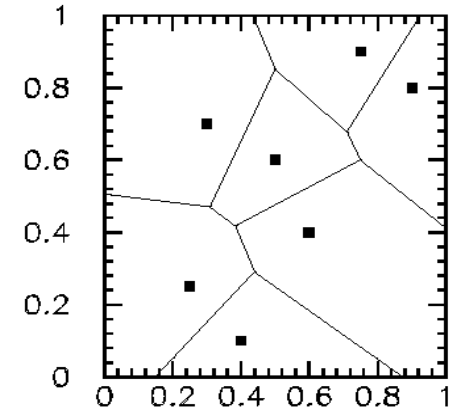
3) Search for regions of excess (more data events than expected from background) within that variable space

For each final state ...

Input: 1 data file, estimated backgrounds

- transform variables into the unit box
- define regions about sets of data points
 - Voronoi diagrams
- define the "interestingness" of an arbitrary region
 - the probability that the background within that region fluctuates up to or beyond the observed number of events
- search the data to find the most interesting region, \mathcal{R}
- determine \mathcal{P} , the fraction of *hypothetical similar experiments* (hse's) in which you would see something more interesting than \mathcal{R}
 - Take account of the fact that we have looked in many different places

Output: \mathcal{R} , \mathcal{P}



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If the data contain no new physics, Sleuth will find \mathcal{P} to be random in $(0,1)$

If we find \mathcal{P} small, we have something interesting

If the data contain new physics, Sleuth will *hopefully* find \mathcal{P} to be small

If we find \mathcal{P} large, is there no new physics in our data?
or have we just missed it?

How *sensitive* is Sleuth to new physics?

Impossible to answer, in general

(Sensitive to *what* new physics?)

But we can provide an answer for specific cases

$t\bar{t}$ provides a reasonable sensitivity check [cf. DØ PRL (1997, 125 pb⁻¹)]

in $e\mu E_T 2j$: find $\mathcal{P} > 2\sigma$ in $\approx 25\%$ of an ensemble of mock experiments

[cf. dedicated search: 2.75σ (3 events with 0.2 expected)]

in $W 4j$: find $\mathcal{P} > 3\sigma$ in $\approx 25\%$ of an ensemble of mock experiments

[cf. dedicated search: 2.6σ (19 events with 8.7 expected) w/o b-tag]

[cf. dedicated search: 3.6σ (11 events with 2.5 expected) w/ b-tag]

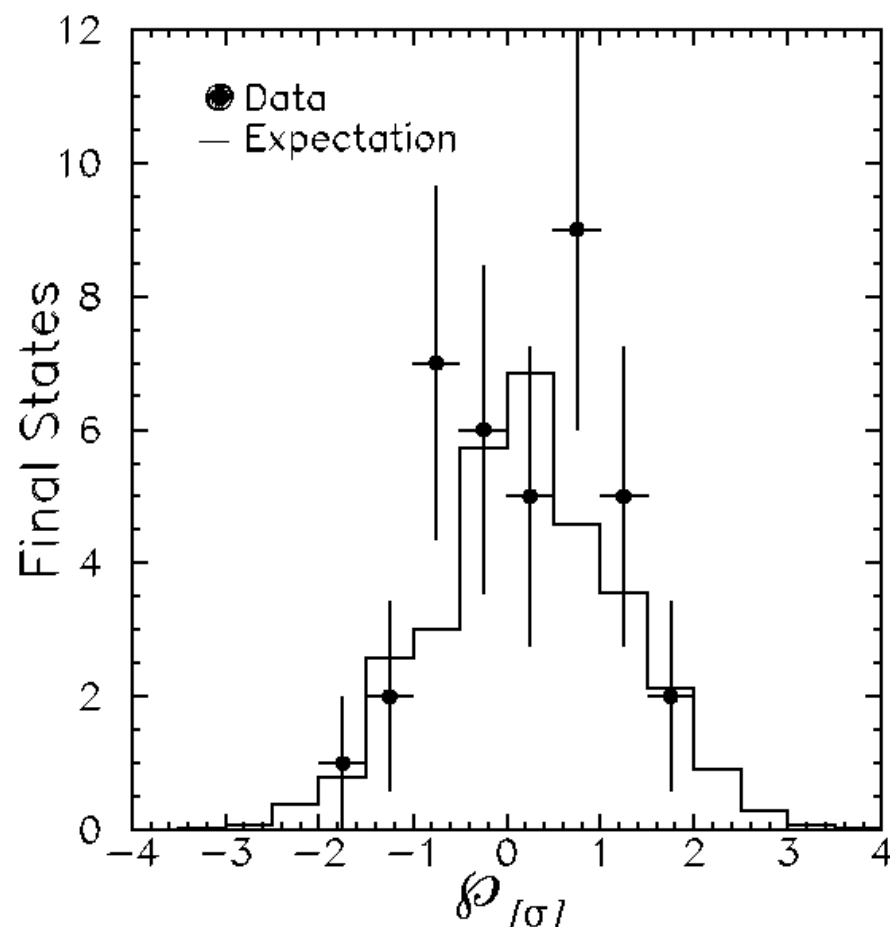
Would we have “discovered” top with Sleuth? **No.**
But results are nonetheless encouraging.

Lessons: b-tagging, combination of channels important for top

other sensitivity checks (WW, leptoquarks) give similarly sensible results

Results

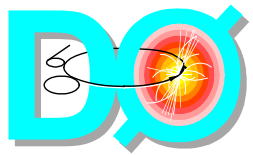
DØ data



Results agree well with expectation

No evidence of new physics is observed

Data set	\mathcal{P}
$e\mu X$	
$e\mu \cancel{E}_T$	0.14 (+1.08 σ)
$e\mu \cancel{E}_T j$	0.45 (+0.13 σ)
$e\mu \cancel{E}_T 2j$	0.31 (+0.50 σ)
$e\mu \cancel{E}_T 3j$	0.71 (−0.55 σ)
$W + \text{jets-like}$	
$W 2j$	0.29 (+0.55 σ)
$W 3j$	0.23 (+0.74 σ)
$W 4j$	0.53 (−0.08 σ)
$W 5j$	0.81 (−0.88 σ)
$W 6j$	0.22 (+0.77 σ)
$e \cancel{E}_T 2j$	0.76 (−0.71 σ)
$e \cancel{E}_T 3j$	0.17 (+0.95 σ)
$e \cancel{E}_T 4j$	0.13 (+1.13 σ)
$Z + \text{jets-like}$	
$Z 2j$	0.52 (−0.05 σ)
$Z 3j$	0.71 (−0.55 σ)
$Z 4j$	0.83 (−0.95 σ)
$ee 2j$	0.72 (−0.58 σ)
$ee 3j$	0.61 (−0.28 σ)
$ee 4j$	0.04 (+1.75 σ)
$ee \cancel{E}_T 2j$	0.68 (−0.47 σ)
$ee \cancel{E}_T 3j$	0.36 (+0.36 σ)
$ee \cancel{E}_T 4j$	0.06 (+1.55 σ)
$\mu\mu 2j$	0.08 (+1.41 σ)
$(\ell/\gamma)(\ell/\gamma)(\ell/\gamma)X$	
eee	0.89 (−1.23 σ)
$Z\gamma$	0.84 (−0.99 σ)
$Z\gamma j$	0.63 (−0.33 σ)
$ee\gamma$	0.88 (−1.17 σ)
$ee\gamma \cancel{E}_T$	0.23 (+0.74 σ)
$e\gamma\gamma$	0.66 (−0.41 σ)
$e\gamma\gamma j$	0.21 (+0.81 σ)
$e\gamma\gamma 2j$	0.30 (+0.52 σ)
$W\gamma\gamma$	0.18 (+0.92 σ)
$\gamma\gamma\gamma$	0.41 (+0.23 σ)
\bar{p}	0.89 (−1.23 σ)



Conclusions



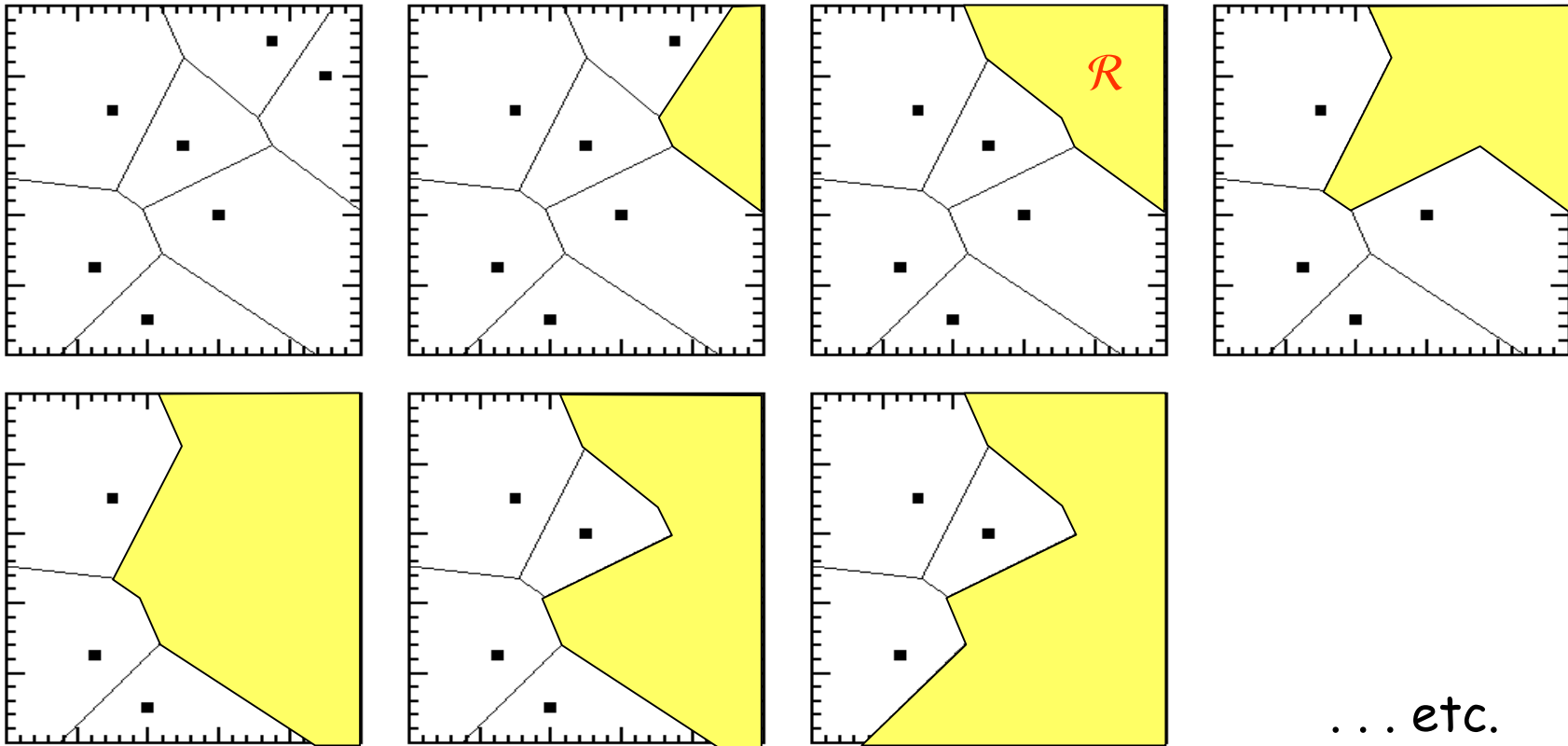
- **Sleuth** is a quasi-model-independent search strategy for new high p_T physics
 - Defines final states and variables
 - Systematically searches for and quantifies regions of excess
- **Sleuth** allows an *a posteriori* analysis of interesting events
- **Sleuth** appears sensitive to new physics
- **Sleuth** finds no evidence of new physics in DØ data
- **Sleuth** has the potential for being a very useful tool
 - Looking forward to Run II

hep-ex/0006011 PRD
hep-ex/0011067 PRD
hep-ex/0011071 PRL

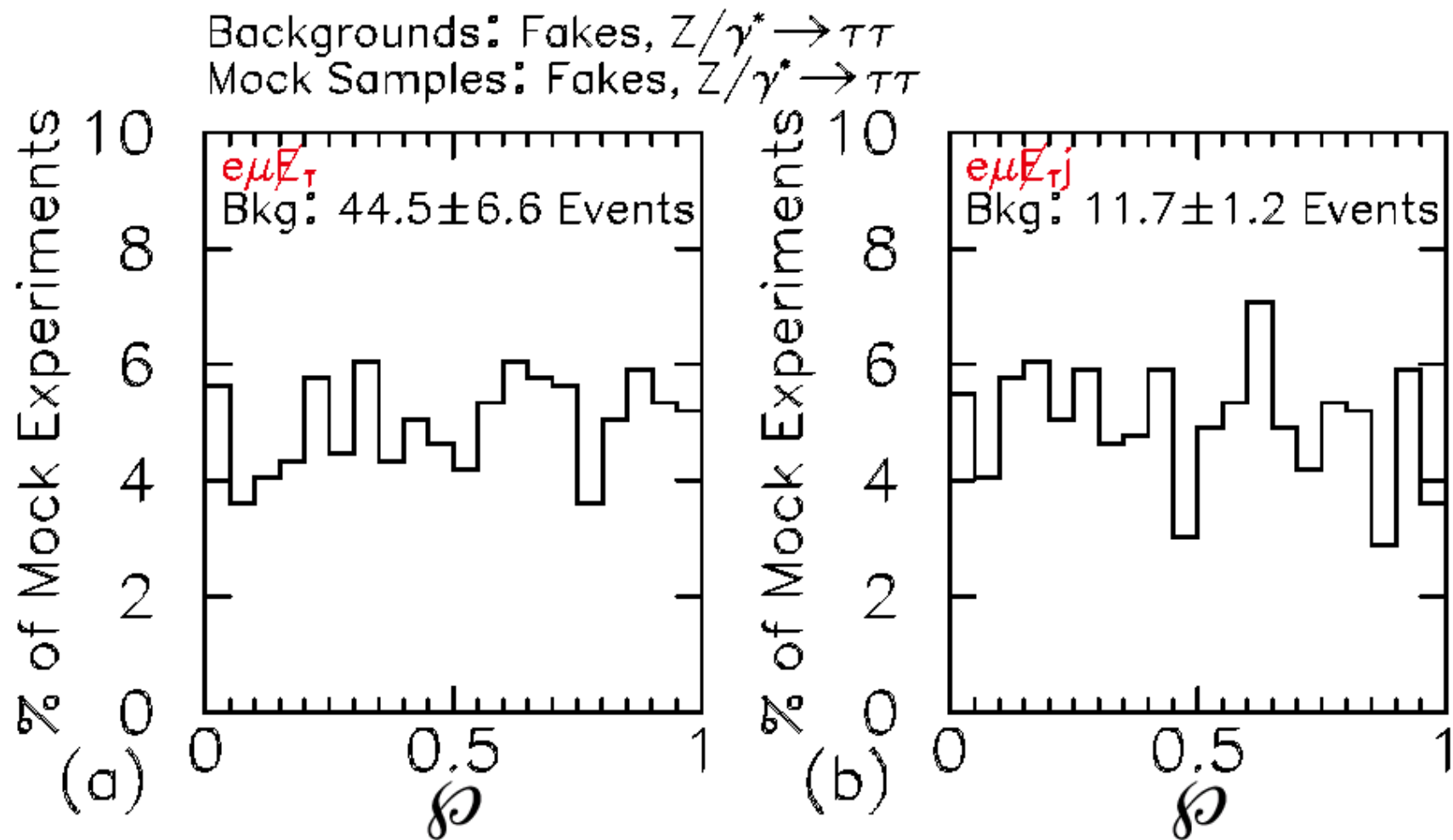
Backup slides



We search the space to find the region of greatest excess, \mathcal{R}



If a data sample contains background only, \mathcal{P} should be a random number distributed uniformly in the interval (0,1)



Results

Sensitivity check: $t\bar{t}$ in $e\mu X$

Let the backgrounds include

- 1)
- fakes
 - $Z \rightarrow \tau\tau$
 - WW
 - $t\bar{t}$

$D\emptyset$ data

Data Set	\mathcal{P}
$e\mu E_T$	$\rightarrow 2.4\sigma$
$e\mu E_{Tj}$	0.4σ
$e\mu E_{Tjj}$	$\rightarrow 2.3\sigma$
$e\mu E_{Tjjj}$	0.3σ
Combined	1.9σ

Excesses corresponding
(presumably)
to WW and $t\bar{t}$

- 2)
- fakes
 - $Z \rightarrow \tau\tau$
 - WW
 - $t\bar{t}$

$D\emptyset$ data

Data Set	\mathcal{P}
$e\mu E_T$	1.1σ
$e\mu E_{Tj}$	0.1σ
$e\mu E_{Tjj}$	$\rightarrow 1.9\sigma$
$e\mu E_{Tjjj}$	0.2σ
Combined	1.2σ

Excess corresponding
(presumably)
to $t\bar{t}$

- 3)
- fakes
 - $Z \rightarrow \tau\tau$
 - WW
 - $t\bar{t}$

$D\emptyset$ data

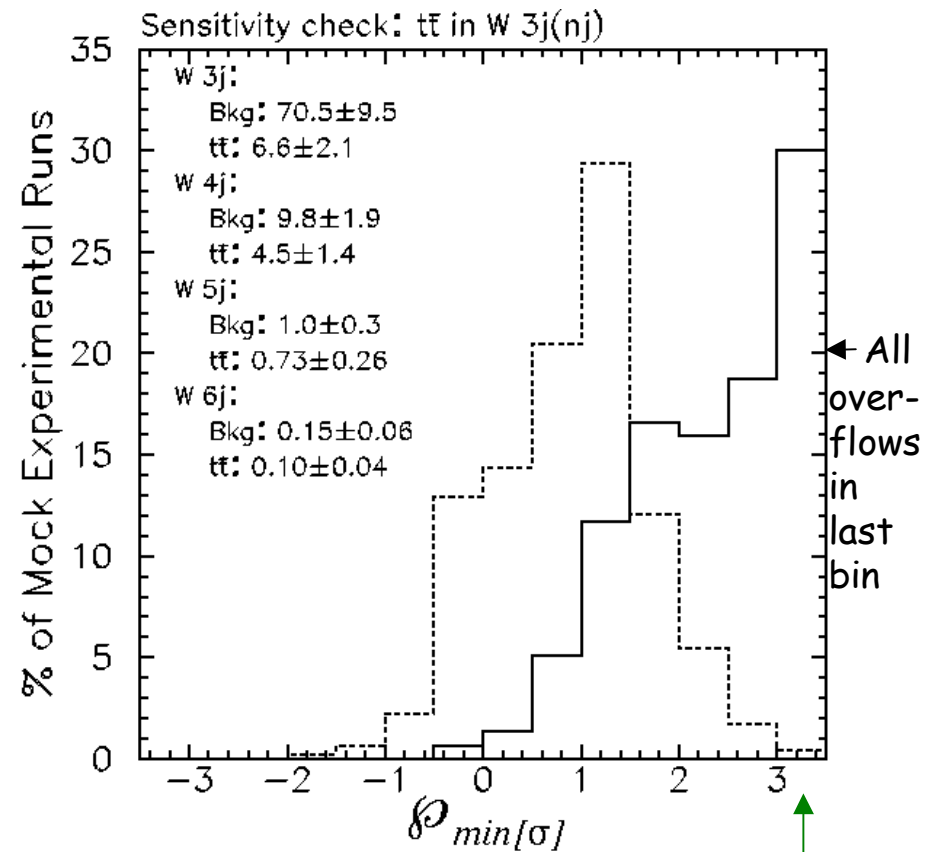
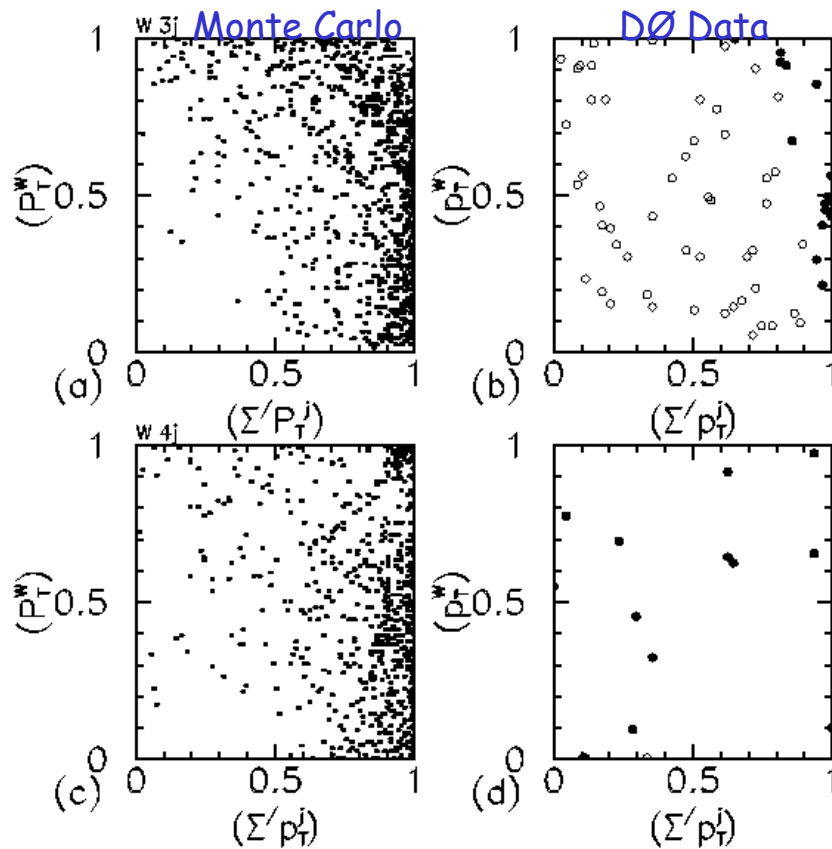
Data Set	\mathcal{P}
$e\mu E_T$	1.1σ
$e\mu E_{Tj}$	0.1σ
$e\mu E_{Tjj}$	0.5σ
$e\mu E_{Tjjj}$	-0.5σ
Combined	-0.6σ

No evidence for new
physics

Results

Sensitivity check: $t\bar{t}$ in $Wjjj(nj)$

Could Sleuth have found $t\bar{t}$ in the lepton+jets channel?



Sleuth finds $\mathcal{P}_{min} > 3\sigma$ in 30% of an ensemble of mock experimental runs

Results

Sensitivity check: Leptoquarks in $eejj$

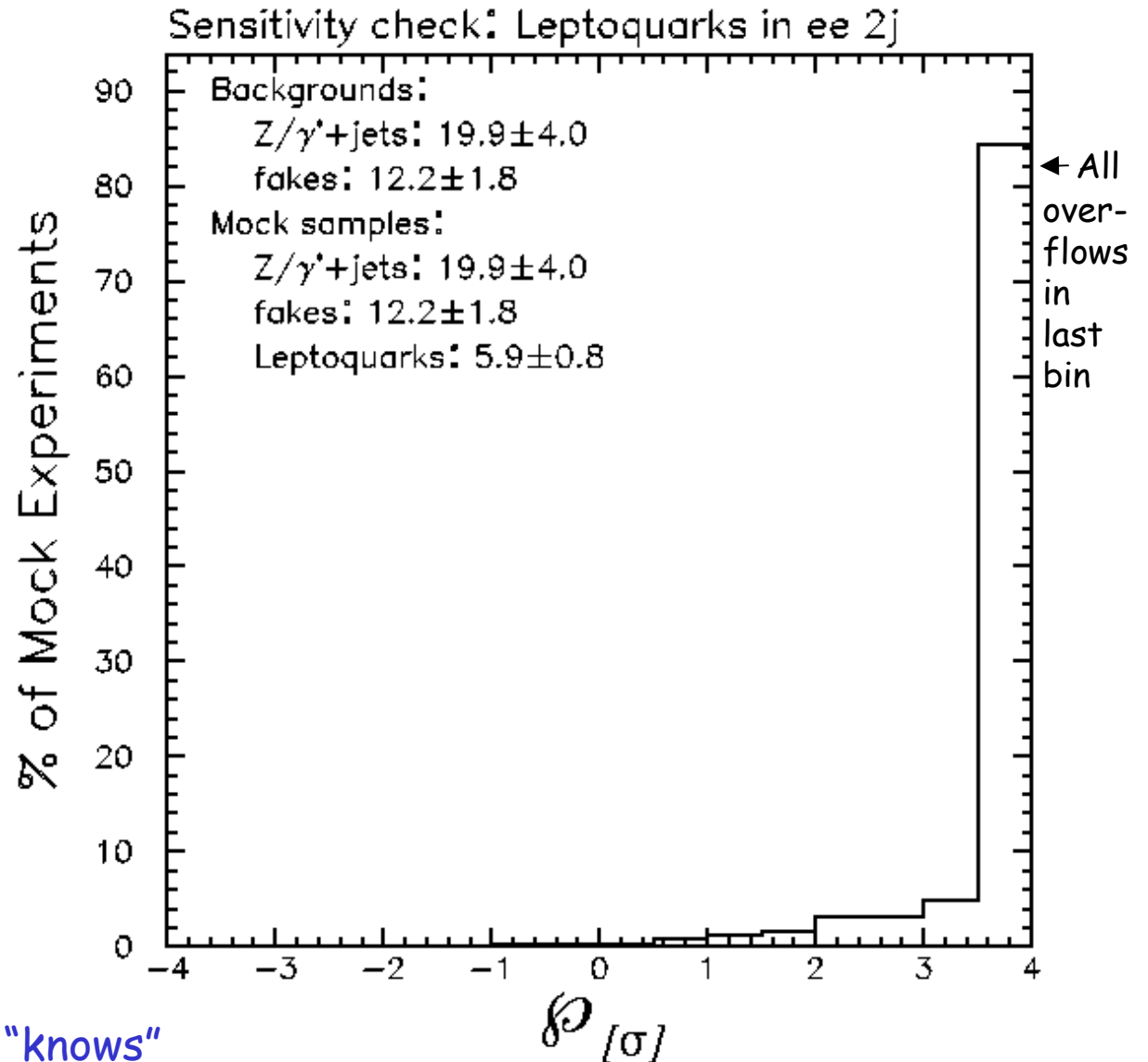
We can run mock experiments with hypothetical signals, too

What if our data contained leptoquarks?

(Assume scalar, $\beta = 1$,
 $m_{LQ} = 170 \text{ GeV}$)

Sherlock finds $\mathcal{P} > 3.5\sigma$
in $> 80\%$ of the mock experiments

(Remember that Sherlock "knows" nothing about leptoquarks!)



Results

Combining many final states

We can account for the fact that we have looked at many different final states by computing $\tilde{\mathcal{P}}$

The correspondence between $\tilde{\mathcal{P}}$ and the minimum \mathcal{P} found for the final states that we have considered is shown here

